What went wrong with symmetries?

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Abstract

The thesis of the article is that the recent crisis in theoretical physics is partially due to the sloppy thinking related to symmetries. This sloppiness manifests itself already in general relativity, in standard model there is no unification of color and electroweak symmetries and their different character is not understood, GUT approach is based on naive extension of gauge group and makes problematic predictions, supersymmetry in its standard form predicted to become visible at LHC energies is now strongly dis-favoured experimentally, and superstring model led to landscape catastrophe what has left is AdS/CFT correspondence which has not led to victories. Could it be that also conformal invariance should be re-considered seriously: a non-trivial generalization to 4-D context is highly desirable so that 10-D bulk would be replaced by 4-D space-time in the counterpart of AdS/CFT duality.

1 Introduction

Theoretical physics is in deep crisis. This is not bad at all. Crisis forces eventually to challenge the existing beliefs. Crisis gives also hopes about profound changes. In physical systems criticality means sensitivity, long range fluctuations and long range correlations, and this makes phase transition possible. In TGD framework life emerges at criticality!

The crisis of theoretical physics has many aspects. The crisis relates closely to the sociology of science and to the only game in the town attitude. The prevailing materialistic philosophy of science combined with the naive length scale reductionism form part of the sad story. The seeds of the crisis were sown in birthdays of quantum mechanics. The fathers of quantum theory were well aware that quantum measurement theory is the Achilles heel of the newborn quantum theory but later the pragmatically thinking theoreticians labelled questioning of the basic concepts as "philosophy" not meant for a respectable physicist.

The recent quantum measurement theory is just a collection of rules and observer still remains an outsider. To my view the proper formulation of quantum measurement theory requires making observer a part of systems. This means that physics must be extended to a theory of consciousness.

This raises several fundamental challenges and questions. How to define "self" as a conscious entity? How to resolve the conflict between two causalities: that of field equations and that of "free will"? What is the relationship between the geometric time of physicist and the experienced time? How is the arrow of time determined and is it always the same? The evidence that living matter is macroscopic quantum system is accumulating: is a generalization of quantum theory required to describe quantum systems? What about dark matter: can we understand it in the framework of existing quantum theory? This list could be continued.

In the following I will not consider this aspect more but restrict the consideration to an important key notion of recent day theoretical physics, namely symmetries. Physical theories rely nowadays on postulates about symmetries and there are many who say that quantum theory reduces almost totally group representation theory. There are refined mathematical tools making possible to derive the implications of symmetries in quantum theory such as Noether's theorem. These technical tools are extremely useful but it seems that methodology has replaced critical thought.

By this I mean that the real nature of various symmetries has not been considered seriously enough and that this is one of the basic reasons for the recent dead end. In the following I describe what I see as the mistakes due to sloppy thinking (maybe "sloppying" might be shorthand for it) and discuss briefly the TGD based solution of the problems involved.

This sloppiness manifests itself already in general relativity, in standard model there is no unification of color and electroweak symmetries and their different character is not understood, GUT approach is based on naive extension of gauge group and makes problematic predictions, supersymmetry in its standard form predicted to become visible at LHC energies is now strongly dis-favoured experimentally, and superstring model led to landscape catastrophe what has left is AdS/CFT correspondence which has not led to victories. Could it be that also conformal invariance should be re-considered seriously: a non-trivial generalization to 4-D context is highly desirable so that 10-D bulk would be replaced by 4-D space-time in the counterpart of AdS/CFT duality.

2 The ways it went wrong

The sloppy thinking about symmetries is characteristic for all of theoretical physics as following examples show. I dare to guess that this is basically due to the "Go to the math library and learn to apply the method" attitude. It helps to produced papers satisfying the criteria for what it is to be "scientific" but the outcome is like music composed by mechanical rules: boring.

2.1 Energy problem of GRT

Energy and momentum are not well-defined notions in General Relativity. The Poincare symmetry of flat Minkowski space is lost and one cannot apply Noether's theorem so that the identification of classical conserved charges is lost and one can talk only about local conservation guaranteed by Einstein's equations realizing Equivalence Principle in weak form.

In quantum theory this kind of situation is highly unsatisfactory since Uncertainty Principle means that momentum eigenstates are delocalized. This is sloppy thinking and the fact that quantization is to high extend representation theory for symmetry groups might well explain the failure of the attempts to quantize general relativity.

TGD was born as a reaction to the challenge of constructing Poincare invariant theory of gravitation. The identification of space-times as 4-surfaces of some higher-dimensional space of form $H = M^4 \times S$ lifts Poincare symmetries from space-time level to the level of imbedding space H.

In this framework GRT space-time is an approximate macroscopic description obtained by replacing the space-time sheets of many-sheeted space-time with single piece of M^4 which is slightly curved. Gravitational fields -deviations of induced metric from Minkowski metric- are replaced with their sum for various sheets. Same applies to gauge potentials. Einstein's equations express the remnants of Poincare symmetry for the GRT space-time obtained in this manner.

In superstring models one actually considers 10-D Minkowski space so that the lifting of symmetries is possible. Also the compactification (say Calabi-Yau) to $M^4 \times C$ still have Poincare symmetries. But after that one has 10-D gravitation and the same problems that one wanted to solve by introducing strings! School example about sloppying!

2.2 Is color symmetry really understood?

Many colleagues use to think that standard model is a closed chapter of theoretical physics. This is a further example of sloppy thinking.

1. Standard model gauge group is product of color and electro-weak groups which are totally independent. The analogy with Maxwell's equations is obvious.

Only after Maxwell and Einstein they could be seen as parts of single tensor representing gauge field.

2. QCD and electroweak interactions differ in crucial manner. Color symmetry is exact (no Higgs fields in QCD) whereas electroweak symmetry is broken, and QCD is asymptotically free unlike electroweak interactions. In QCD color confinement takes place at low energies and remains still poorly understood.

Again TGD approach suggests a solution to these problems in terms of induced gauge field concept and a more refined view about QCD color.

1. $S = CP_2$ has color group SU(3) as isometries and electroweak gauge group as holonomies: hence CP_2 unifies these symmetries just like Maxwell's theory unified electric and magnetic fields. Note that the choice of $H = M^4 \times CP_2$ is not adhoc: its factors are the only 4-D spaces allowing twistor spaces with Kähler structure.

2. One can understand also the different nature of these symmetries. Color group represents exact symmetries so that symmetry breaking should not take place. Holonomies are tangent space symmetries and broken already at the level of CP_2 geometry and does not therefore give rise to genuine Noether symmetries. One can however assign broken electroweak gauge symmetries to the holonomies.

   The isometry group defines Kac-Moody algebra in quantum TGD and color group acts as Kac-Moody group rather than gauge group. The differences is very delicate since only the central extension of Kac-Moody algebra distinguishes it from gauge algebra.

3. Color is not spin-like quantum number as in QCD but colored states correspond to color partial waves in CP_2 rather. Both leptons and quarks allow colored excitations which are however expected to be very heavy.

2.3 Is Higgs mechanism only a parameterization of particle masses?

The discovery of Higgs at LHC was very important step of progress but did not prove Higgs mechanism as a mechanism of massivation as sloppy thinkers believe. Fermion masses are not a prediction of the theory: they are put in by hand by assuming that Higgs couplings are proportional to the Higgs mass. It might well be that Higgs vacuum expectation value is the unique quantum field theoretic representation of particle massivation but that QFT approach cannot predict the masses and that the understanding of the massivation requires transcending QFT so that one describing particles as extended objects. String models were the first step to this direction but one step was not enough.

In TGD framework more radical generalization is performed. Point-like particle is replaced with a 3-surface and particle massivation is described in terms of p-adic thermodynamics, which relies on very general assumptions such as a non-trivial generalization of 2-D conformal invariance to 4-D context to be discussed later, p-adic thermodynamics, p-adic length scale hypothesis, and mapping of the predictions for p-adic mass squared to real mass squared by what I call anonical identification.

Higgs vacuum expectation has a counterpart also in basic TGD. Weak gauge bosons are classically components of spinor connection so that gauge invariance at quantum level is a well-motivated hypothesis. Gauge boson massivation follows from p-adic thermodynamics. As one calculates the amplitudes for Higgs decays one obtains couplings of Higgs to gauge boson pair with coeffecient proportional to a dimensional parameter identifiable as counterpart of Higgs expectation in QFT description.

2.4 GUT approach as more sloppy thoughts

After the successes of standard model the naive guess was that theory of everything could be constructed by a simple trick: extend the gauge group to a larger group containing standard model gauge group as sub-group. One can do this and there is a refined machinery allowing to deduce particle multiplets, effective actions, beta functions, etc.. There exists of course an infinite variety of Lie groups and endless variety of GUTs have been proposed.

The view about the Universe provided by GUTs is rather weird looking.

1. Above weak mass scale there should be a huge desert of 14 orders of magnitudes containing no new physics! This is like claiming that the world ends at my backyard.

2. Only the sum of baryon and lepton numbers would be conserved and proton would be unstable. The experimental lower limit for proton lifetime has been however steadily increasing and all GUTs derived from superstring models share a fine tuning to keep proton alive.

3. Standard model gauge group seems to be all that is needed: there are no indications for larger gauge group. Fermion families seem to be copies of each other with different mass scales. Also the mass scales of these fermions differ dramatically and forcing them to multiplets of single gauge group could also be sloppy thinking. One would expect that the masses differ by simple numerical factors but they do not.

From TGD viewpoint the GUT approach is un-necessary.

1. In TGD quarks and leptons correspond to different chiralities of imbedding space spinors. 8-D chiral invariance implies that quark and lepton numbers are separately conserved so that proton does not decay - at least in the manner predicted by GUTs. CP_2 mass scale is of same order of magnitude as the mass scale assigned to the super heavy additional gauge bosons mediating proton decay.

2. Family replication phenomenon does not require extension of gauge group since fermion families correspond to different topologies for partonic 2-surfaces representing fundamental particles (genus-generation correspondence [K1]). Note

that the orbits of partonic 2-surfaces correspond to light-like 3-surface at which the induced metric changes its signature from Euclidian to Minkowskian: these surfaces or equivalently the 4-surfaces with Euclidian signature can be regarded as lines of generalized Feynman diagrams.

The three lowest genera are special in the sense that they always allow Z_2 as global conformal symmetry whereas higher genera allow this symmetry only in case of hyper-elliptic surfaces: this leads to an explanation for the experimental absence of higher genera. Higher genera could be more naturally many particle states with continuum mass spectrum with handles taking the role of particles.

3. p-Adic length scale hypothesis emerging naturally in TGD framework allows to understand the mass ratios of fermions which are very un-natural if different fermion families are assumed to be related by gauge symmetries.

2.5 Supersymmetry in crisis

Supersymmetry is very beautiful generalization of the ordinary symmetry concept by generalizing Lie-algebra by allowing grading such that ordinary Lie algebra generators are accompanied by super-generators transforming in some representation of the Lie algebra for which Lie-algebra commutators are replaced with anti-commutators. In the case of Poincare group the super-generators would transform like spinors. Clifford algebras are actually super-algebras. Gamma matrices anti-commute to metric tensor and transform like vectors under the vielbein group (SO(n) in Euclidian signature). In supersymmetric gauge theories one introduced super translations anti-commuting to ordinary translations.

Supersymmetry algebras defined in this manner are characterized by the number of super-generators and in the simplest situation their number is one: one speaks about $\mathcal{N} = 1$ SUSY and minimal super-symmetric extension of standard model (MSSM) in this case. These models are most studied because they are the simplest ones. They have however the strange property that the spinors generating SUSY are Majorana spinors- real in well-defined sense unlike Dirac spinors. This implies that fermion number is conserved only modulo two: this has not been observed experimentally. A second problem is that the proposed mechanisms for the breaking of SUSY do not look feasible.

LHC results suggest MSSM does not become visible at LHC energies. This does not exclude more complex scenarios hiding simplest $\mathcal{N} = 1$ to higher energies but the number of real believers is decreasing. Something is definitely wrong and one must be ready to consider more complex options or totally new view abot SUSY.

What is the analog of SUSY in TGD framework? I must admit that I am still fighting to gain understanding of SUSY in TGD framework [K6]. That I can still imagine several scenarios shows that I have not yet completely understood the problem but I am working hardly to avoid falling to the sin of sloppying myself.

The basic question is whether covariantly constant right handed neutrino generators $\mathcal{N} = \in$ SUSY or whether the SUSY is generated as approximate symmetry by adding massless right-handed neutrino to the state thus changing its four-momentum. The problem with the first option is that it the standard norm of the state is naturally proportional to four-momentum and vanishes at the limit of vanishing four-momentum: is it possible to circumvent this problem somehow? In the following I summarize the situation as it seems just now.

1. In TGD framework $\mathcal{N} = 1$ SUSY is excluded since B and L and conserved separately and imbedding space spinors are not Majorana spinors. The possible analog of space-time SUSY should be a remnant of a much larger super-conformal symmetry in which the Clifford algebra generated by fermionic oscillator operators giving also rise to the Clifford algebra generated by the gamma matrices of the "world of classical worlds" (WCW) and assignable with string world sheets. This algebra is indeed part of infinite-D super-conformal algebra behind quantum TGD. One can construct explicitly the conserved super conformal charges accompanying ordinary charges and one obtains something analogous to $\mathcal{N} = \infty$ super algebra. This SUSY is however badly broken by electroweak interactions.

2. The localization of induced spinors to string world sheets emerges from the condition that electromagnetic charge is well-defined for the modes of induced spinor fields. There is however an exception: covariantly constant right handed neutrino spinor ν_R: it can be de-localized along entire space-time surface. Right-handed neutrino has no couplings to electroweak fields. It couples however to left handed neutrino by induced gamma matrices except when it is covariantly constant. Note that standard model does not predict ν_R but its existence is necessary if neutrinos develop Dirac mass. ν_R is indeed something which must be considered carefully in any generalization of standard model.

2.5.1 Could covariantly constant right handed neutrinos generate SUSY?

Could covariantly constant right-handed spinors generate exact $\mathcal{N} = 2$ SUSY? There are two spin directions for them meaning the analog $\mathcal{N} = 2$ Poincare SUSY. Could these spin directions correspond to right-handed neutrino and antineutrino. This SUSY would not look like Poincare SUSY for which anti-commutator of super generators would be proportional to four-momentum. The problem is that four-momentum vanishes for covariantly constant spinors! Does this mean that the sparticles generated by covariantly constant ν_R are zero norm states and represent super gauge degrees of freedom? This might well be the case although I have considered also alternative scenarios.

2.5.2 What about non-covariantly constant right-handed neutrinos?

Both imbedding space spinor harmonics and the modified Dirac equation have also right-handed neutrino spinor modes not constant in M^4 and localized to the partonic orbits. If these are responsible for SUSY then SUSY is broken.

1. Consider first the situation at space-time level. Both induced gamma matrices and their generalizations to modified gamma matrices defined as contractions of imbedding space gamma matrices with the canonical momentum currents for Kähler action are superpositions of M^4 and CP_2 parts. This gives rise to the

mixing of right-handed and left-handed neutrinos. Note that non-covariantly constant right-handed neutrinos must be localized at string world sheets.

This in turn leads neutrino massivation and SUSY breaking. Given particle would be accompanied by sparticles containing varying number of right-handed neutrinos and antineutrinos localized at partonic 2-surfaces.

2. One an consider also the SUSY breaking at imbedding space level. The ground states of the representations of extended conformal algebras are constructed in terms of spinor harmonics of the imbedding space and form the addition of right-handed neutrino with non-vanishing four-momentum would make sense. But the non-vanishing four-momentum means that the members of the super-multiplet cannot have same masses. This is one manner to state what SUSY breaking is.

2.5.3 What one can say about the masses of sparticles?

The simplest form of massivation would be that all members of the super-multiplet obey the same mass formula but that the p-adic length scales associated with them are different. This could allow very heavy sparticles. What fixes the p-adic mass scales of sparticles? If this scale is CP_2 mass scale SUSY would be experimentally unreachable. The estimate below does not support this option.

One can consider the possibility that SUSY breaking makes sparticles unstable against phase transition to their dark variants with $h_{eff} = n \times h$. Sparticles could have same mass but be non-observable as dark matter not appearing in same vertices as ordinary matter! Geometrically the addition of right-handed neutrino to the state would induce many-sheeted covering in this case with right handed neutrino perhaps associated with different space-time sheet of the covering.

This idea need not be so outlandish at it looks first.

1. The generation of many-sheeted covering has interpretation in terms of breaking of conformal invariance. The sub-algebra for which conformal weights are n-tuples of integers becomes the algebra of conformal transformations and the remaining conformal generators do note represent gauge degrees of freedom anymore. They could however represent conserved conformal charges still.

2. This generalization of conformal symmetry breaking gives rise to infinite number of fractal hierarchies formed by sub-algebras of conformal algebra and is also something new and a fruit of an attempt to avoid sloppy thinking. The breaking of conformal symmetry is indeed expected in massivation related to the SUSY breaking.

The following poor man's estimate supports the idea about dark sfermions and the view that sfermions cannot be very heavy.

1. Neutrino mixing rate should correspond to the mass scale of neutrinos known to be in eV range for ordinary value of Planck constant. For $h_{eff}/h = n$ it is reduced by factor $1/n$, when mass kept constant. Hence sfermions could be stabilized by making them dark.

2. A very rough order of magnitude estimate for sfermion mass scale is obtained from Uncertainty Principle: particle mass should be higher than its decay rate. Therefore an estimate for the decay rate of sfermion could give a lower bound for its mass scale.

3. Assume the transformation $\nu_R \rightarrow \nu_L$ makes sfermion unstable against the decay to fermion and ordinary neutrino. If so, the decay rate would be dictated by the mixing rate and therefore to neutrino mass scale for the ordinary value of Planck constant. Particles and sparticles would have the same p-adic mass scale. Large h_{eff} could however make sfermion dark, stable, and non-observable.

2.5.4 A rough model for the neutrino mixing in TGD framework

The mixing of right- and left handed neutrinos would be the basic mechanism in the decays of sfermions.The mixing mechanism is mystery in standard model framework but in TGD it is implied by both induced and modified gamma matrices. The following argument tries to capture what is essential in this process.

1. Conformal invariance requires that the string ends at which fermions are localized at wormhole throats are light-like curves. In fact, light-likeness gives rise to Virasosoro conditions.

2. Mixing is described by a vertex residing at partonic surface at which two partonic orbits join. Localization of fermions to string boundaries reduces the problem to a problem completely analogous to the coupling of point particle coupled to external gauge field. What is new that orbit of the particle has corner at partonic 2-surface. Corner breaks conformal invariance since one cannot say that curve is light-like at the corner. At corner neutrino transforms from right-handed to left handed one.

3. In complete analogy with $\overline{\Psi}\gamma^t A_t \Psi$ vertex for the point-like particle with spin in external field, the amplitude describing $nu_R - \nu_L$ transition involves matrix elements of form $\overline{\nu}_R \Gamma^t(CP_2) Z_t \nu_L$ at the vertex of the CP_2 part of the modified gamma matrix and classical Z^0 field.

   How Γ^t is identified? The modified gamma matrices associated with the interior need not be well-defined at the light-like surface and light-like curve. One basis of weak form of electric magnetic duality the modified gamma matrix corresponds to the canonical momentum density associated with the Chern-Simons term for Kähler action. This gamma matrix contains only the CP_2 part. It will be found that the light-likeness of the virtual momenta implies that the covariant derivative along string boundary vanishes so that the explicit form of modified gamma does not actually matter.

The following provides as more detailed view.

1. Let us denote by $\Gamma^t_{CP_2}(in/out)$ the CP_2 part of the modified gamma matrix at string at at partonic 2-surface and by Z^0_t the value of Z^0 gauge potential

along boundary of string world sheet. The direction of string line in imbedding space changes at the partonic 2-surface. The question is what happens to the modified Dirac action at the vertex.

2. For incoming and outgoing lines the equation $D(in/out)\Psi(in/out) = p^k(in, out)\gamma_k\Psi(in/out)$, where the modified Dirac operator is $D(in/out) = \Gamma^t(in/out)D_t$, is assumed. ν_R corresponds to "in" and ν_R to "out". It implies that lines corresponds to massless M^4 Dirac propagator and one obtains something resembling ordinary perturbation theory. Light-likeness implies that the covariant derivative of induced spinor field along the string boundary must vanish. This is indeed possible since the projections of gauge potentials are pure gauge by 1-dimensionality.

   This also implies that the residue integration over fermionic internal momenta gives as a residue massless fermion lines with non-physical helicities as one can expect in twistor approach. For physical particles the four-momenta are massless but in complex sense and the imaginary part comes classical from four-momenta assignable to the lines of generalized Feynman diagram possessing Euclidian signature of induced metric so that the square root of the metric determinant differs by imaginary unit from that in Minkowskian regions.

3. In the vertex $D(in/out)$ could act in $\Psi(out/in)$ and the natural idea is that $\nu_R - \nu_L$ mixing is due to this so that it would be described the classical weak current couplings $\overline{\nu}_R\Gamma^t_{CP_2}(out)Z^0_t(in)\nu_L$ and $\overline{\nu}_R\Gamma^t_{CP_2}(out)Z^0_t(in)\nu_L$.

4. This description should generalize also to the construction of more general vertices. All of them should should have similar fermionic 1-1 fermion vertices as a building bricks. Manifest gauge invariance might be achieved if the counterpart of gauge field at vertex is the difference of gauge potentials along string associated with the Minkowskian and Euclidian sides of the partonic orbit. This could appear also in the above construction instead of gauge potential.

   Also the assumption that the induced W boson fields are pure gauge at string world sheets is a challenge. According the previous proposal, the fundamental fermion and anti-fermion at the opposite throats of bosonic wormhole contact must preserve their em charges and become throats of physical outgoing fermion and anti-fermion. Also a pair of new wormhole throats associated as second wormhole throat the the physical fermions must be created.

To get some idea about orders of magnitude assume that the CP_2 projection of string boundary is geodesic circle thus describable as $\Phi = \omega t$, where Φ is angle coordinate for the circle and t is Minkowski time coordinate. The contribution of CP_2 to the induced metric g_{tt} is $\Delta g_{tt} = -R^2\omega^2$.

1. In the first approximation string end is a light-like curve in Minkowski space meaning that CP_2 contribution to the induced metric vanishes. Neutrino mixing vanishes at this limit.

2. For a non-vanishing value of ωR the mixing and the order of magnitude for mixing rate and neutrino mass is expected to be $R \sim \omega$ and $m \sim \omega/h$. p-Adic

length scale hypothesis and the experimental value of neutrino mass allows to estimate m to correspond to p-adic mass to be of order eV so that the corresponding p-adic prime p could be $p \simeq 2^{167}$. Note that $k = 127$ defines largest of the four Gaussian Mersennes $M_{G,k} = (1+i)^k - 1$ appearing in the length scale range 10 nm -2.5 μm. Hence the decay rate for ordinary Planck constant would be of order $R \sim 10^{14}$/s but large value of Planck constant could reduced it dramatically. In living matter reductions by a factor 10^{-12} can be considered.

2.6 Have we been thinking sloppily also about super-conformal symmetries?

Super string models were once seen as the only possible candidate for the TOE. By looking at the proceedings of string theory conferences one sees that the age of super strings is over. Landscape problem and multiverse do not give much hopes about predictive theory and the only defence for super string models is as the only game in the town. Super string gurus do not know about competing scenarion but this is not a wonder given the fact that publishing of competing scenarios has been impossible since superstrings have indeed been the only game in the town! One of the very few almost-predictions of superstring theory was $\mathcal{N} = 1$ SUSY at LHC and it seems that it is already now excluded at LHC energies.

AdS/CFT correspondence (http://en.wikipedia.org/wiki/AdS/CFT_correspondence) is a deep mathematical discovery inspired by super-string models. One of its variants states that there is duality between conformal theory in M^4 appearing as boundary of 5-D AdS and string theory in 10-D space $AdS_5 \times S^5$. A more general duality would be between conformal theory in M^n and 10-D space $AdS_{n+1} \times S^{10-n-1}$. For $n = 2$ the CFT would give conformal theory at 2-D Minkowski space for which conformal symmetries (actually their hypercomplex variant) form an infinite-D group. Duality has interpretation in terms of holography but the notion of holography is much more general than AdS/CFT.

AdS/CFT have been applied to nuclear physics but nothing sensational have been discovered. AdS/CFT have been tried also to explain the finding that what was expected to be QCD plasma behaves very differently. The first findings came from RHIC for heavy ion collisions and LHC has found that the strange effects appear already for proton heavy ion collisions. Essentially a deviation from QCD predictions is in question and in the regime where QCD should be a good description. AdS/CFT has not been a success (http://backreaction.blogspot.com/2011/10/adscft-confronts-data.html). AdS/CFT is now applied also to condensed matter physics. At least hitherto no dramatic successes have been reported.

This leads to ask whether sloppy thinking should be blamed again. AdS/CFT is mathematically rather sound and well-tested but is the notion of conformal invariance behind it really the one that applies to real world physics?

1. In TGD framework the ordinary conformal invariance is generalized so that it becomes 4-D one: of course, the ordinary finite-dimensional conformal group in M^4 is not in question. The basic observation is that light-like 3-surfaces are metrically 2-dimensional and that this leads to a generalization of conformal

transformations. One can locally express light-like 3-surfaces as $X^2 \times R$ and what happens is that the conformal transformations of X^2 are localized with respect to the light-like coordinate of R. Light-like orbits of partonic 2-surfaces carrying elementary particle quantum numbers would have this extended conformal invariance.

2. This is not all. In zero energy ontology (ZEO) the diamond like intersections of future and past directed light-cones - causal diamonds (CDs) are the basic objects. The space-time surfaces having 3-D ends at the boundaries of CD are the basic dynamical units. The boundaries of CD are pieces of $\delta M^4_\pm \times CP_2$. The boundary $\delta M^4_\pm = S^2 \times R_+$ is light-like 3-surface and thus allows a huge extension of conformal symmetries: with complex coordinate of S^2 and light-like radial coordinate playing the roles of complex coordinate for ordinary conformal symmetry.

   Besides this there is a further analog of conformal symmetry. The symplectic transformations of $\delta M^4_\pm \times CP_2$ can be regarded as symplectic transformations of $S^2 \times CP_2$ localized with respect to the light-like coordinate of R_+ defining the analog of the complex coordinate z. In TGD Universe a gigantic extension of the conformal symmetry of superstring models experiences applies.

3. Even these extended symmetries extend to a multi-local (loci correspond to partonic 2-surfaces at boundaries of CD) Yangian variant [K5, K3, **?**]. Yangian symmetry is very closely related to quantum groups studied for decades but again without serious consideration of the question "Why quantum groups?". The hazy belief has been that they somehow emerge at Planck length scale, which itself is a hazy notion based solely on dimensional analysis and involving Planck constant and Newton's constant characterizing macroscopic gravitation.

   In TGD framework hyper-finite factors of type II_1 [K4] emerge naturally at the level of WCW since fermionic Fock space provides a canonical representation for them and their inclusions provide an elegant description for finite measurement resolution: the included algebra generates states which are not experimentally distinguishable from the original state.

4. Against this it is astonishing that AdS/CFT duality has very simple generalization in TGD framework and emerge from a generalization of General Coordinate Invariance (GCI) [K2] implying holography. Strong form of GCI postulates that either the space-like 3-surfaces at the ends of causal diamonds or the light-like orbits of partonic 2-surfaces can be taken as 3-surfaces defining the WCW: this is just gauge fixing for general coordinate invariance. If this is true then partonic 2-surfaces and their 4-D tangent space data at the boundaries of CD must code for physics. One would have strong form of holography. This might be too much to require: string world sheets carrying induced spinor fields are present and it might be that they cannot be reduced to data at partonic 2-surfaces.

   In any case, for this duality the 10-D space of AdS/CFT duality would be replaced with space-time surface. M^n would be replaced with the light-like parton orbits and/or space-like ends of CD. Surprisingly, this holography would be very much like holography in its original form!

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